AC vs. DC Transmission System Modeling

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AC Transmission System Model

- An AC transmission system model is a more accurate model of a power system
- Why do we even talk about not modeling the system with an AC model?
  - Difficult Solution or possibly no solution exists
  - More, and *more complex*, input data required
    - Switched Shunt, Transformer Tap, Generator Var control methodologies
    - DC Transmission Line Modeling (these devices *consume* lots of Vars)
    - Much more…

Making a "DC" approximation: the "DC" Power Flow

- First, a word about confusing nomenclature
- "DC Power Flow" is a *confusing* term
  - This has nothing to do with direct current systems, nothing to do with DC Transmission
  - A better term would have been "linearized lossless"
  - Term "DC" is used because the form of the mathematical equations look very similar to a direct current equations

What assumptions are made by the DC approximation?

- Voltage magnitudes are assumed to be 1.0 per unit
  - This is not required, but is typically done
  - We could assume constant voltage magnitudes instead
- Terms that cause system losses are removed from the equations (series line conductance)
  - Note: assumption is NOT that line resistance (r) is zero
  - The assumption is that r << x
  - When line series admittance is calculated

$$g + jb = \frac{1}{r + jx} = \frac{r}{r^2 + x^2} + j\frac{-x}{r^2 + x^2}$$

$$g = \frac{r}{r^2 + x^2} \approx 0$$

What is gained by making the DC approximation?

- Equations are much simpler and easier to solve and will solve for reliably
- Much less input data to manage
  - This can be very important for the practical use of any software
- Solution speeds are much better

What is lost by making the DC approximation?

- Aggregate losses disappear
  - 2–4% of the system demand just disappears!
- The effect of marginal losses on generator dispatch is ignored
  - In an AC solution, software can penalize generators that increase system losses in a dispatch algorithm using the loss sensitivities calculated from the AC equations
  - DC equations inherently have no losses, so these sensitivities can be calculated from the AC system
- Transmission Line Var flows are ignored
  - If we assume Var = 0, then the MW limit become the MVA limit
  - This means that transmission lines may carry more MWs than is really possible
- Voltage control modeling is ignored
  - Transformer tap, Switched Shunts, Gen Var, DC Line Vars, etc…

Can some of what was lost be "added" back into the DC approximation?

- YES, for the first three bullet points on the previous slide can be approximated inside the DC approximation
  - Aggregate Losses
  - Marginal Losses
  - Line Var flows
- Voltage control modeling can not be "added".

Modeling Aggregate Losses in the DC approximation

- We can "bring aggregate losses back"
- Increase the loads in your system when using the DC approximation so that they reflect the combination of loads and losses.
  - One solution: look at the ratio of losses to load in each zone of the system.
  - Then increase loads throughout that zone uniformly to reflect losses

Modeling Loss Sensitivities in the DC Approximation

- We can include the effect of marginal losses on dispatch
- DC equations inherently have no losses, so these loss sensitivities must be determined elsewhere
  - Possibly calculate the loss sensitivities from an external AC solution
- Problem: When should we update these loss sensitivities in our modeling?
  - Loss sensitivities are highly dependent on system operating conditions.
  - A real-time market could use a DC-based model for the market calculations, but feed in loss sensitivities from the real-time AC model of the previous hour.

Modeling Transmission Var Flows in the DC Approximation

- The impact of Var flows on the MW flows of the system can be modeled
- If a constant voltage magnitude is assumed at every bus, then modeling Var flows on transmission lines in the DC approximation is possible
  - Assuming constant voltage magnitudes, the Var flow on a transmission line can be directly calculated from the MW flow on the line (lookup Power Circles in a textbook)
- In a dispatch algorithm, the Var flow can inherently be included by *derating* the limit of the transmission line

Modeling Voltage Control Issues in the DC Approximation

- Modeling Voltage issues using a DC approximation is not possible
- Voltage issues can not be included
- Voltage/Var related control devices can not be included
- If you need to model these, you can't use the DC approximation

What would I recommend?

- For short-term analysis looking 1 day to several weeks ahead – use the Full AC model if you have the input data required.
- Looking beyond this time frame, use a DC approximation
  - However, keep in mind that you can retain some characteristics of the AC model without increasing complexity too much.